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FARMERS' BULLETIN 864

UNITED STATES DEPARTMENT OF AGRICULTURE

PRACTICAL INFORMATION *for* BEGINNERS *in* IRRIGATION

Rev. ed. follows

FUTURE development of lands now unoccupied in Government and private irrigation projects in the United States must be accomplished largely by settlers from humid regions who are not experienced in irrigation farming. This bulletin contains suggestions aimed to assist such farmers to master the details of preparing land for irrigation, laying out and building farm ditches, and handling the water supply so as to assure the best results.

Contribution from the Bureau of Public Roads

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PRACTICAL INFORMATION FOR BEGINNERS IN IRRIGATION.

CONTENTS.

SEVERAL million acres of land in the United States are under irrigation works built by private enterprise and the National Government, which have been settled recently or are awaiting settlement. Settlers have come and are likely to come from humid regions, where many of the methods used in irrigated farming are neither practiced nor understood, and unless an opportunity is given them to become familiar with proper methods their efforts may result in failure.

The first few pages of this bulletin contain some suggestions to those who are confronted with the task of selecting a farm under an irrigation system. Arid soils and water supplies are considered in a general way from the standpoint of the irrigator. The greater part of the paper is taken up with a somewhat fuller description of how to locate and build farm ditches, how to prepare land to receive water, how to irrigate a few of the staple crops, and how much water to apply.

SELECTION AND LOCATION OF AN IRRIGATED FARM.

Climate and crops.—The intending settler, in deciding where to locate, will be guided to some extent by the climate and the crops which can be grown profitably. Those who prefer a mild winter climate will be naturally attracted to the southern belt of the arid States, which includes Texas, New Mexico, Arizona, southern Nevada, and the greater part of California. Those who prefer cooler summers, coupled with short winters of frost and snow, will find a location suited to their tastes in the central belt, extending from western Kansas through Colorado, Utah, northern Nevada, and north on the

Pacific slope to eastern Oregon and Washington. Those who come from northern latitudes will do well to consider Nebraska, the Dakotas, Wyoming, Idaho, and Montana. The soil, climatic conditions, cost of water, and area to be irrigated will determine to a large extent the crops to be grown.

Character and depth of soil.—In choosing land which is to be irrigated a careful examination should be made of the character and depth of the soil, its behavior when irrigated, the slope and evenness of the surface, the presence of injurious salts, and the facilities for drainage. One of the best indications of the character of the soil is the native vegetation which grows on it. When sagebrush, buffalo grass, or cactus is found on a tract, it is reasonably certain that the soil is fertile, easily tilled, and well drained, although additional drainage may be necessary when the land is irrigated. The plants named are but a few out of a large group which grow on good soil, easily irrigated. On the other hand, the presence of greasewood, creosote bush, saltwort, salt weeds, or other similar plants are indicative of a heavier soil, less easily cultivated, and containing more or less of the injurious salts usually grouped under the common name of alkali.

In arid regions plants draw their supply of plant food and moisture from considerable depths, and the deeper the soil the larger is the feeding ground for the roots and the greater is the capacity of the soil to store water. In the warmer parts of the West the top layer of soil is used chiefly as a sort of blanket to protect the moist soil beneath, which furnishes both food and water to the fibrous roots. The presence of any hard, impervious stratum lying between the first and fifth foot prevents deep rooting and the storage of moisture. A hard stratum lying between the fifth and tenth foot is likewise injurious, but to a less extent. On the other hand, a porous stratum of coarse gravel may cause the waste of large quantities of irrigation water by permitting it to percolate beyond the root zone. It, however, indicates good drainage and is more desirable than an impervious subsoil. The character of the subsoil may be readily determined by boring holes with a suitable soil auger to a depth of 10 feet, if necessary, and taking samples of soil at different depths.

Absorption of water by the soil.—Easily irrigated soil will absorb sufficient water in 24 hours after an irrigation to become moist to a depth of 2 or 3 feet. Some soils are so impervious that it is difficult to wet more than a few inches below the surface and others are so porous that the water soon percolates through them beyond the reach of the deepest roots. The surface of other soils bakes and cracks after each wetting, rendering cultivation difficult and increasing losses by evaporation. Usually it will be possible to find similar soils under

irrigation in near-by fields, but if this is not possible a trial may be made on a small scale to determine how the soil acts under irrigation. In general, sandy loams irrigate well, while clay does not absorb water readily, is hard to cultivate when wet, and bakes and cracks when drying.

Surface conditions.—The intending purchaser should likewise examine with much care the nature of the ground surface. The best conditions are a smooth surface, with a uniform slope of 10 to 20 feet to the mile. It costs little to put such land in shape for the spreading of water over it, and the slope favors good drainage. At the other extreme one finds land full of buffalo or hog wallows or covered with sand dunes and hummocks. These alternating heights and hollows are difficult to reduce to an even grade. Again, the land may be cut up by ravines, thereby increasing the labor and cost of putting water upon it, or it may have too much or too little slope. If land which is naturally smooth on the surface and of the right slope costs $5 per acre to put in shape for irrigating, hog-wallow land or that covered with sand dunes may cost $15. Thus it is evident that the cost of preparing the surface is an important consideration in the first cost of the land. Besides, some hog-wallow land is inferior in quality, being charged with injurious salts.

Drainage.—Good drainage is essential for a permanently productive irrigated farm. It is practically impossible to supply crops with sufficient water for the best growth without applying so much that some will seep into the subsoil. Unless this can flow away it will raise the level of the ground water until it comes near the surface, where it may drown out crops and cause an accumulation of alkali. If land has not good natural drainage, it must be supplied artificially, but this need not be done until a few crops have been raised.

THE WATER SUPPLY.

How irrigation water is obtained.—The water supply for a farm in any one of the Western States and Territories may be obtained from the unappropriated waters of a natural stream, from underground sources, from a canal company which has water rights to sell, or from one of the Government irrigation projects, but usually a single tract can secure water from only one source. Under favorable conditions a single farmer may secure a water supply from a natural source, but more frequently it requires the united effort of a number of farmers. Before diverting water from a stream the individual or manager of a company should first seek advice from the proper State officials. In most of the western Commonwealths the appropriation, diversion, and distribution of the public waters have been placed under the supervision and control of a State engineer or a State

board of irrigation, and information may be obtained from these officials regarding the regulations governing the appropriation and diversion of water, the flow in any particular stream, the volumes which have been appropriated and used, and the balance, if any, which is subject to appropriation. Information may also be obtained from subordinate officials who have immediate charge of distributing water. In States which have no officers to regulate and control the distribution of water, the intending settler would do well to get the opinion of some reliable lawyer who is familiar with existing rights to the use of water in the neighborhood. Some local engineer also may be profitably consulted with reference to the amount and reliability of the water supply from a particular source.

Reservoirs and pumping.—In the older districts, where the stream flow in summer has been appropriated, there are situations where a supply can be obtained by building a storage reservoir or by installing a pumping plant. Small enterprises of this character may be undertaken by individuals, associations, or mutual companies. A large number of small and medium-size reservoirs have been built by the farmers living in the basins of the Cache la Poudre and Big Thompson Rivers, in northern Colorado. In southern California, in Santa Clara Valley, and in portions of the San Joaquin Valley a large part of the water supply is obtained by pumping water from wells.

Large canals.—The most common source of water supply for the new settlers in irrigated districts is likely to be an irrigation canal built by private enterprise or by the Government for the purpose of supplying water to farmers. Before completing arrangements to take water from a private company one should make a careful examination of its ability to furnish an adequate supply at such times as will best meet the needs of the crops to be grown. A few of the most important features of canal water rights are outlined in the following paragraphs:[1]

(1) Under the doctrine of appropriation, which is the governing principle of the law in most of the Western States, when two or more canal companies or individuals take water from the same stream, which is subject to wide fluctuations in flow, those whose rights were acquired last are the first to suffer when scarcity exists. Between the rights of those who were the first to divert water and the rights of those who were last there is a wide range of conditions which vitally affect the value of the water rights. Some canals have an abundance of water throughout the crop-growing season; others carry a full volume during the flood season and a diminished volume

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[1] For a fuller discussion of canal water rights, see Dept. Bul. 913; Irrigation Institutions, by Elwood Mead (New York, 1903); Irrigation in the United States, by R. P. Teele, (New York, 1915); Dept. Bul. 913, U. S. D. A.

during the remainder of the time. Some fail to provide an adequate supply for the last irrigation of such crops as alfalfa and potatoes, while others are likely to have their entire supply shut off after the spring floods have subsided. Thus it is apparent that there are all sorts of canal rights to the use of water, and the value of a water user's right to a portion of the volume carried by a canal will depend to a large extent on the nature of the stream from which the supply is taken, the priority of the canal, the number of water rights sold, the amount allowed for each irrigation or for the season, and the general efficiency of the system.

(2) Companies dispose of the water conveyed in canals by making contracts with individual owners. A few years ago the prevailing type of contract was one providing for the sale of a perpetual water right for a given tract of land, with an additional annual charge for the operation and maintenance of the canal system, but this type is not now common. Under some canals the purchase of a water right is not required, the total charge for water being paid annually in the way of water rental. The system of disposing of water rights now most common, is the sale, along with the land to be irrigated, of rights which carry an interest in the works supplying water, so that the works become the property of the landowners when a fixed portion of the rights have been paid for. When the land to be irrigated is included in an irrigation district there is no purchase of a water right, since the ownership carries with it a right to water from the works belonging to the district. The cost of these works is levied against the land in the form of taxes, and is not included in the purchase price of the land.

(3) Contracts vary much as to the quantity of water which the companies agree to furnish. Probably the most common is a stream of a given size, say 1 cubic foot per second for each 80 acres of land, on condition that the purchaser will turn off the water when it is not needed. Others agree to furnish enough to cover the land to a given depth, say 2 feet, during each season. Practically all such contracts provide, however, that in case of shortage of water the company shall "prorate" what water it has. That is, in case the company has not enough water to supply all it has contracted to deliver, it shall divide what it has among all its contract holders. Few canals have all the time enough water to fill all contracts, and the effect of such a contract is that the purchaser is to receive a share of what water the company gets rather than a stream of a given size or a fixed quantity during the season; the share received depending on the number of water rights sold. The effect in mutual companies is the same. The settler buys, instead of a water right, a share in the company, and each share entitles its holder to a portion of what-

ever water the canal carries. The same is true in irrigation districts. In fact, under practically every form of water right not directly from a stream, the farmer gets a share of the available supply rather than a fixed quantity. Under most contracts a short supply does not decrease the charge to the customer. This shows the necessity for paying as much attention to the rights of the company as to the form of the contract.

(4) The value of contract water rights likewise depends on the way the canal is managed. Care and efficiency in maintenance and operation, equitable distribution of water, and sufficient resources to meet all necessary expenses are important factors in determining the value of water rights.

(5) Attention should also be given to the permanency and stability of the canal system. Floods and fire frequently destroy canal structures, and before they can be repaired crops may suffer or perish for lack of water. So, also, breaks are likely to occur at the weak points and the repairing of these necessitates the turning off of the supply, which injuriously affects the owners of water rights.

Government works.—Water for irrigation purposes may be obtained also at the stipulated price per acre from one of the Government irrigation projects. When the Government undertakes to furnish water to lands in private ownership it does so through a water users' association, in which all of the landowners within the project become shareholders in the association, or through an irrigation district. The cost of a water right under a Government project varies from $22 to $200 per acre. This sum is payable in 20 annual installments, and a failure to make any two payments when due may forfeit the right. When the payments for the water for the major portion of the land under any project have been made, the operation and management of the irrigation system, exclusive of all storage reservoirs, passes to the owners of the lands irrigated, to be maintained and operated at their expense. The cost will then be a pro rata share of the actual operating expenses. Information regarding location, prices, and terms can be obtained by addressing the Director of the United States Reclamation Service, Washington, D. C.

FARM DITCHES.

Whatever the source of supply, a network of ditches to convey the water to all parts of the farm is necessary. The larger ditches and canals need not be considered in this connection, for they usually are built by contractors under competent engineers; but the location and building of farm ditches is done in most instances by the farmers without assistance from engineers or surveyors. The following features of farm ditches are briefly discussed for the benefit of the inexperienced:

The capacity needed depends chiefly on the manner of delivering the water and the method used in applying it. It also depends, but to a less extent, on the size of the farm, the duty of water, the nature of the soil, and the crops raised. In this discussion capacities of ditches are given generally in cubic feet per second. Throughout the West the "miner's inch" is very commonly used. In southern California, Idaho, Kansas, New Mexico, North Dakota, South Dakota, Nebraska, and Utah 50 miner's inches equal 1 cubic foot per second; in Arizona, Nevada, Montana, Oregon, and central California 40 miner's inches equal 1 cubic foot per second; and in Colorado 38.4 miner's inches are commonly considered equal to 1 cubic foot per second.

In Montana, Wyoming, and Idaho, as well as in parts of other States, water usually is delivered in continuous streams which for an average size farm seldom exceed 2 cubic feet per second. The supply ditches for the farms accordingly are small, except for the large holdings.

In Utah, New Mexico, Arizona, California, and to some extent in other States, water is delivered to the user during short periods of time, with long intervals when the supply is shut off entirely. The stream delivered is larger than when water is delivered continuously, and the volume delivered depends on the way it is applied and the time of use.

In the citrus orchards of California the size of the streams delivered varies from 30 to 60 miner's inches. At Riverside, where the soil is a clay loam, the usual allotment is 30 inches for 48 hours once a month or 30 inches for 72 hours every six weeks on a 10-acre tract, although the tendency is to shorten the intervals between irrigations. Around Pomona, where the soil is sandy, the usual size of stream is from 50 to 60 inches, the larger stream running for a shorter time.

On the diversified farms of Utah and Colorado the supply ditches vary in capacity from 1 to 3 cubic feet per second.

In irrigating alfalfa and meadows by the border and check methods of irrigation, as practiced in Arizona, California, New Mexico, and Nevada, and in the use of water during the rainy winter seasons of the Pacific coast, large volumes are used. Supply ditches accordingly are built to carry 6 to 10 cubic feet per second. The size must be determined with reference to the crops to be grown, their acreage, the method to be adopted in watering them, and the regulations governing the delivery of water.

Where laterals or ditches are to be crossed by farm roads or highways a suitable form of structure must be adopted as the case demands. Figure 1 shows a small bridge crossing a lateral, but where smaller ditches are to be crossed a culvert consisting of concrete or

corrugated pipe with suitable headwalls may be introduced. Care should be taken to set the inside bottom of the pipe at the same elevation as the bed of the ditch, and a pipe large enough in diameter to care for the full capacity of the ditch should be used. Sufficient

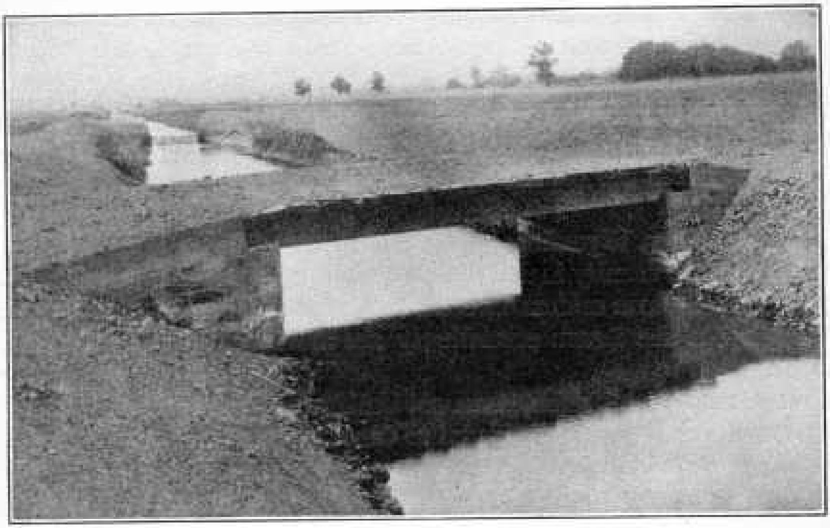

FIG. 1.—Farm wagon bridge across small lateral.

earth should be graded over the pipe to form an adequate cushion to absorb impact and to keep the tires of vehicles from coming into direct contact with the surface of the pipe.

FORM.

The form depends largely on the implements used in making the excavation. Figures 2 and 3 represent the cross sections of two

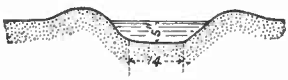

FIG. 2.—Farm ditch No. 1.

FIG. 3.—Farm ditch No. 2.

ditches made by ditch plows attached to sulky frames. The ditches are cleaned out afterwards by hand. The first of these is made with a 14-inch lister or double-mold board plow and will carry from ½ to

FIG. 4.—Farm ditch No. 3.

1½ cubic feet per second, depending on the grade, and the second is made with a 16-inch lister and will carry ½ to 2 cubic feet per second. The ditch shown in figure 4 is a somewhat larger one and is intended

to carry $1\frac{1}{2}$ to 5 cubic feet per second. It may be made by first plowing a strip where the ditch is to be and then removing the loose soil by a scraper or V-shaped crowder (fig. 5).

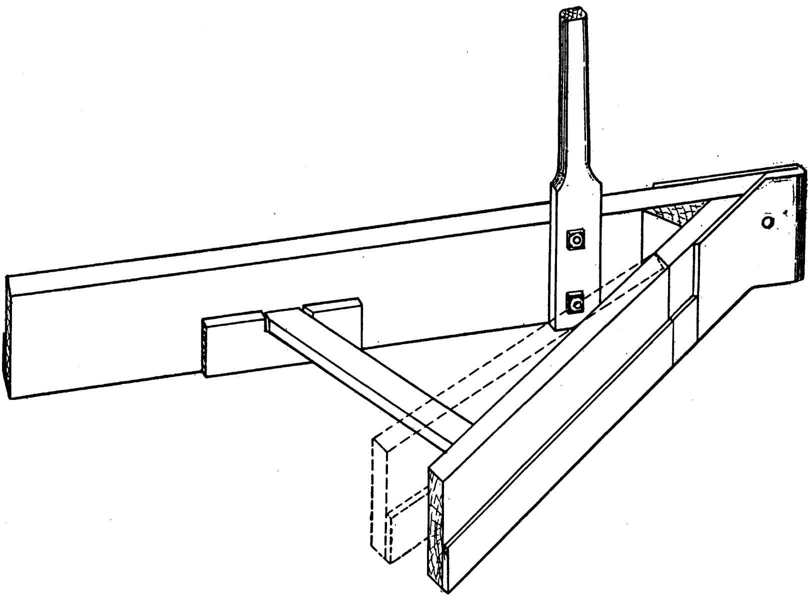

FIG. 5.—Adjustable "V" scraper or crowder.

Farm ditch No. 4, which has a capacity of 3 to 10 cubic feet per second, according as the grade is flat or steep, may be made trapezoidal, as shown in figure 6, or curved, as shown in figure 7. The

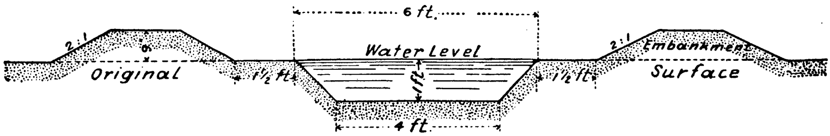

FIG. 6.—Farm ditch No. 4.

first represents the cross section of a ditch made by one of the many kinds of graders which remove the earth from the excavation and deposit it on the embankments at some little distance from the edge.

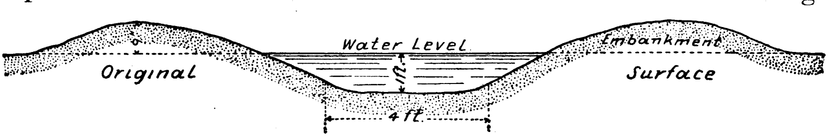

FIG. 7.—Farm ditch No. 4.

The second represents the cross section of a ditch made with a plow and scraper, or else by a plow and one of the many kinds of homemade devices used for removing loose dirt from ditches.

Two forms likewise may be given to the ditch shown in figures 8 and 9, which has a capacity of 9 to 25 cubic feet per second, depending on the grade. A ditch of this size often is built by an association of farmers to convey water to a number of ranches. The manner of building both kinds is similar to that shown in figures 5 and 6.

GRADE.

Capacity and grade.—The quantity of water which a ditch will carry depends fully as much on the fall or grade as on its size. The two elements must be considered together. When conditions are

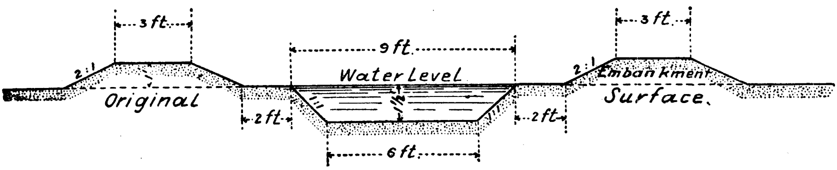

FIG. 8.—Farm ditch No. 5.

such that one has a choice as to grade the chief points in mind are the volume to be carried and the nature of the soil. The smaller the volume the greater the grade required to produce a given velocity. In a small ditch capable of carrying 1 cubic foot per second a fall of 2 inches to the rod would produce a velocity of 2 feet per second, while in a ditch capable of carrying 20 cubic feet per second the fall required to give the same velocity is only one-fourth inch to the rod. In fine sand or sediment a flat grade is required in order to prevent scouring. A mean velocity of 1 foot per second is sufficient for such material. In hard gravel or hard clay, or in a mixture of these, a

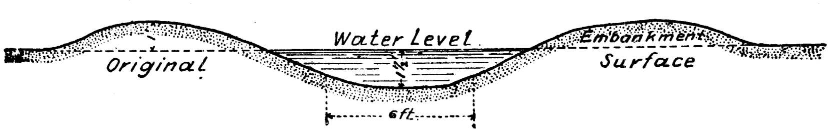

FIG. 9.—Farm ditch No. 5.

velocity of 3 feet per second can be used without eroding the bottom. In ordinary materials, ranging from sandy or gravelly loams to clay loams, a grade may be safely adopted which will produce a mean velocity of 2 to 2½ feet per second. On a farm with little fall the grade of a ditch can not exceed that of the land. On rolling land or where the slope is steep a suitable grade for ditches usually can be found by running them across the slopes rather than directly down them. When excessive grades can not be avoided by winding around the high places the speed of the water may be checked by the insertion of drops at proper intervals. Check boards are convenient to divert water into laterals, and at a slight additional expense they may be combined with permanent drops.

Flow of water in farm ditches.—In the table which follows, the flow in each of the five types of farm ditches previously shown (figs. 2 to 9) has been figured for different grades. These grades are intended to cover ordinary conditions on most farms and are expressed in three ways: First, in inches and fractions of an inch per rod; next in feet per 100 feet; and, lastly, in feet per mile. The mean or average velocity of the water in each kind of ditch having a given grade is given also, as well as the discharge in cubic feet per second and its equivalent in miner's inches under a 6-inch pressure head, about 40 of such inches being equal to 1 cubic foot per second. Thus in farm ditch No. 4 a grade of ½ inch per rod produces a discharge of 4.2 cubic feet per second, but when the grade is increased to ¾ inch per rod the discharge is 5.2 cubic feet per second.

Table giving the mean velocity and discharge of ditches with different grades.

FARM DITCH NO. 1.—FIGURE 2.

Grade.			Mean velocity in feet per second.	Discharge.	
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.	Miner's inches under 6-inch pressure head.
½	0.25	13.33	1.01	0.67	27
¾	.38	20.00	1.23	.81	32
1	.51	26.67	1.42	.93	37
1¼	.63	33.33	1.59	1.05	42
1½	.76	40.00	1.75	1.16	46
2	1.01	53.33	2.04	1.35	54
2½	1.26	66.67	2.28	1.50	60
3	1.51	80.00	2.50	1.64	66
3½	1.77	93.33	2.70	1.78	71

FARM DITCH NO. 2.—FIGURE 3.

¼	0.13	6.67	0.82	0.80	30
½	.25	13.33	1.16	1.00	42
¾	.38	20.00	1.42	1.30	52
1	.51	26.67	1.64	1.50	60
1¼	.63	33.33	1.84	1.70	67
1½	.76	40.00	2.02	1.80	74
1¾	.88	46.67	2.18	2.00	80
2	1.01	53.33	2.34	2.10	86
2½	1.26	66.67	2.61	2.40	96

FARM DITCH NO. 3.—FIGURE 4.

⅛	0.06	3.33	0.79	2.08	83
¼	.13	6.67	1.13	3.00	119
½	.25	13.33	1.60	4.20	168
¾	.38	20.00	1.97	5.20	207
1	.51	26.67	2.28	6.00	239
1¼	.63	33.33	2.57	6.80	270

Table giving the mean velocity and discharge of ditches with different grades—Continued.

FARM DITCH NO. 4.—FIGURES 6 AND 7.

Grade.			Mean velocity in feet per second.	Discharge.	
Inches per rod.	Feet per 100 feet.	Feet per mile.		Cubic feet per second.	Miner's inches under 6-inch pressure head.
1/16	0.03	1.58	0.84	4.20	168
1/8	.06	3.33	1.08	5.40	216
1/4	.13	6.67	1.54	7.70	308
3/8	.19	10.00	1.89	9.50	378
1/2	.25	13.33	2.20	11.00	440
5/8	.31	16.67	2.45	12.20	490
3/4	.38	20.00	2.69	13.40	538

FARM DITCH NO. 5.—FIGURES 8 AND 9.

1/16	0.03	1.67	1.03	11.6	464
1/8	.06	3.33	1.48	16.7	666
3/16	.09	5.00	1.82	20.5	819
1/4	.13	6.67	2.11	23.7	950
5/16	.16	8.33	2.35	26.4	1,058
3/8	.19	10.00	2.58	28.0	1,121
7/16	.22	11.67	2.80	30.5	1,260

The weir is the simplest to install and operate and the most commonly used of the various devices for measuring water on the farm.

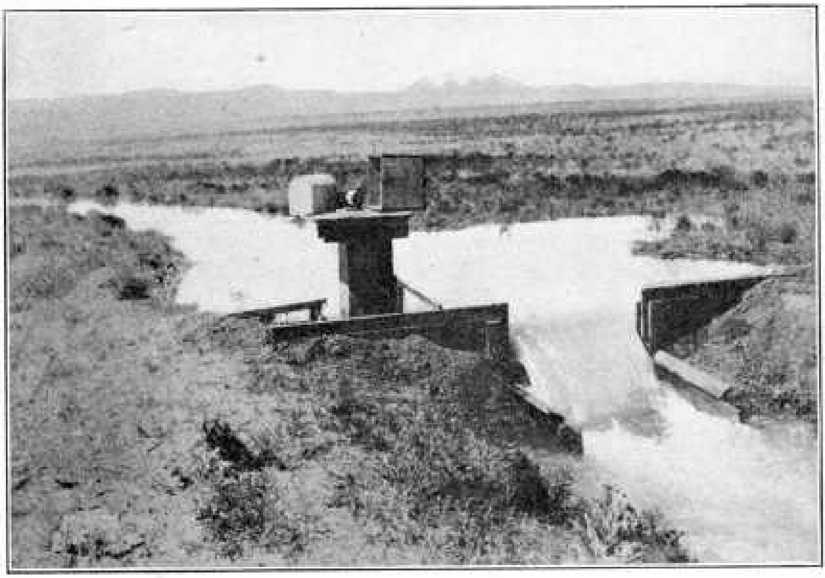

FIG. 10.—Rectangular weir and recording device.

Two types of these are shown in figures 10 and 11 and are known as the rectangular and the Cipolletti weir, respectively. The former

of these types is possibly the most satisfactory for general farm installations, because of the necessity of introducing special arrangements when the Cipolletti weir is used. Specifications for the construction, installation, and use of farm weirs are given in Farmers' Bulletn 813.

Figure 12 shows a measuring box on a concrete-lined ditch. The orifice on the right-hand side of the outlet box is under pressure while the long overflow crest on the left permits the return of the surplus to the ditch.

PLAN AND LOCATION.

Proper location of ditches.—Farm ditches should be located properly. It is a mistake to build ditches for the lower part of a farm and then,

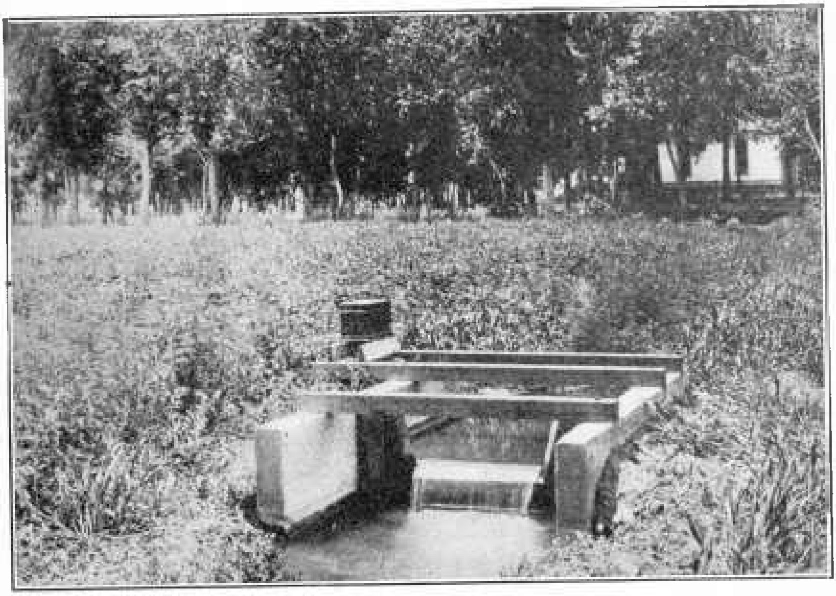

FIG. 11.—Cipoletti weir used in a farm system.

in after years, when there is a desire to irrigate the remainder, to be obliged to build a second series of ditches for the higher land. Sufficient water to irrigate the entire area should first be conveyed from the canal or other source of supply to the highest point of the farm and from there distributed to the various subdivisions. In laying out these permanent ditches an effort should be made to locate them along field or fence boundaries, if possible, in order not to obstruct the passage of teams and implements in fields. When the grade is too steep to permit this a curved location through fields should be chosen. These curved locations for supply ditches can be laid out so as to add greatly to the beauty of an irrigated farm.

They become the margins of fields, by the side of which lanes are graded, fences built, and shade trees planted. The plan of locating supply ditches around the margins of square or rectangular tracts is perhaps better for farm operations when topographic conditions permit.

Ditches on uneven land.—It often happens that a farm is more or less cut up by ravines or depressions which intersect or separate fields, and the supply ditches have to be extended across these low places. This usually is done in one of three ways. When the depression is not more than a few feet deep levees are built on each side; in other cases wooden or metal flumes are built on grade from side to side,

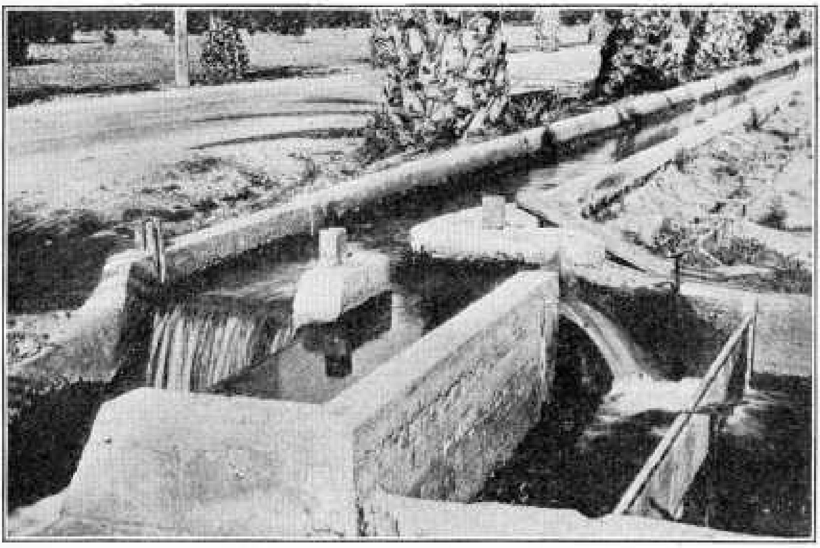

FIG. 12.—Measuring box installed on concrete-lined ditch.

and, lastly, the water may be carried across in a pipe laid in the form of an inverted siphon. The earth levee is the cheapest, but it is subject to leaks and washouts for the first few years. The wooden flume answers the purpose fairly well, but it is subject to early decay, and the clay or cement pipe laid beneath the surface, although more expensive in first cost, is really the cheapest in the end.

Control of weeds.—The margins of supply ditches on most irrigated farms are the breeding ground of weeds. The seeds of these fall into the water and are widely scattered by the irrigation stream. The banks of ditches should be graded and smoothed so that the weeds which grow along the sides can be readily cut and burned. A rapid-growing forage crop like alfalfa also tends to keep down the weeds and may be sown along the banks for this purpose. The right of way may be fenced and sheep pastured on it.

Instruments needed in laying out ditches.—In laying out supply ditches an engineer's level and rod are the most convenient instruments. The distances may be estimated by pacing. When such instruments are not available, a useful substitute consists of an ordinary carpenter's spirit level attached to a portable wooden frame, a sketch of which is shown in figure 13. When first made and placed

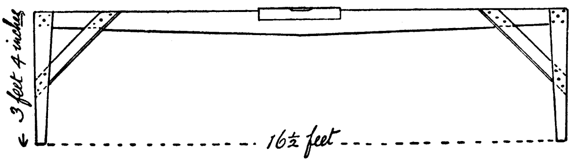

Fig. 13.—Homemade level.

on a level surface the bubble should come to the center of its run. Then one leg is shortened by the amount of the grade per rod (see table of grades). The device is operated by one man, who first places the shorter leg at the surface of the water in the main canal or supply ditch and swings the other end around until the bubble

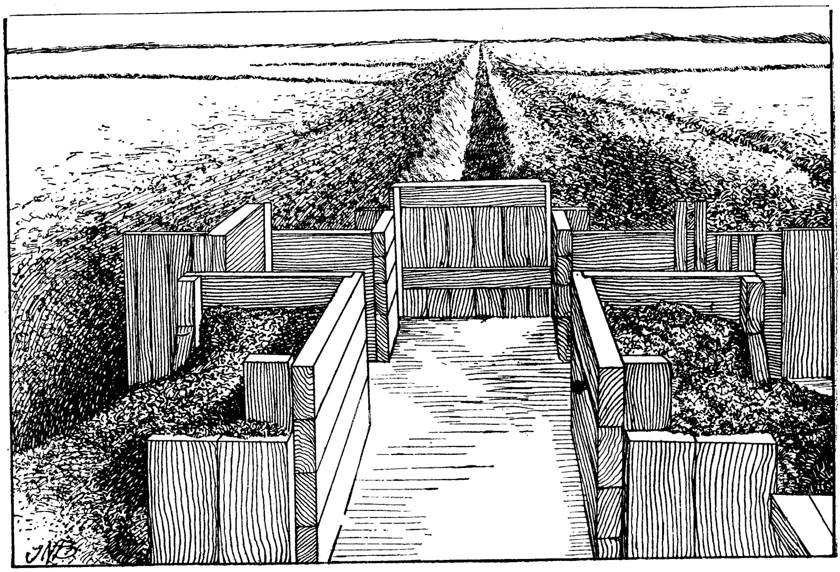

Fig. 14.—Division box in lateral.

comes to the center. The location of the longer leg is then marked by a helper, who carries short stakes for this purpose. The level is then carried forward until the shorter leg occupies the position vacated by its mate, when a second stake is driven. This operation is repeated until the line is laid out. A furrow is then run connecting all of the temporary marks.

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PREPARATION OF LAND FOR IRRIGATION.

The preparation of land for irrigation should follow the building of supply ditches. While this rule is frequently disregarded, it will be found better to grade land in conformity to permanent ditches already constructed than to locate and excavate ditches to suit land that has been graded and leveled. Field ditches, however, are located after the land is leveled.

Importance of surface preparation.—The new settler in an irrigated district seldom appreciates the importance of preparing the surface of fields so that they may be cheaply, easily, and uniformly watered. Crops in an arid climate are as a rule good or bad according as they have received the proper amount of water at the right time, and when the ground is left so rough and uneven that water can not be evenly applied the effect is shown in the reduced yield. The preparation of the land is a first cost, and if it is done thoroughly during the first or second year, little expense need be incurred afterwards. The difference in cost between a smooth well-graded field and one that is poorly graded and rough may not exceed $8 per acre, yet this sum is often lost in one season by diminished yields due to imperfect watering, caused by a rough, uneven surface. Thorough preparation of the surface applies with particular force to a crop like alfalfa, which grows year after year from the roots, and which is cut from three to six times each season.

Contour surveys.—It is difficult to plan a proper system of irrigation for a farm without the aid of preliminary surveys. In addition to the establishment of the boundaries of the farm, the configuration of the surface should be determined by contour surveys from 6 to 12 inches apart in vertical elevation, and the character of the soil and subsoil should likewise be determined by borings or the digging of pits. Knowing the surface elevations and the character of the soil, it is possible to secure suitable locations for farm laterals, adjust the shape and size of the several fields, and adopt a method of applying water which will be in keeping with the local conditions. There is an urgent need for a general plan of irrigation for the entire farm, even though only a small part be reclaimed the first few years of occupation. Too often the importance of this is not realized at first, the result being a wrong start which is extremely difficult to correct in later years. To be more specific, farm ditches are located in the wrong places; the fields are not of the right shape to be readily watered; water flows too far in furrows and strips; the fruit and shade trees are not planted in the right places or in the right directions; and all permanent structures including fences and lanes call for an overhauling and resetting.

Removal of native vegetation.—That portion of arid America which can be reclaimed by cultivation and irrigation is more or less covered with native vegetation of one sort or another. Tracts which produce native grasses, low cacti, rabbit brush, and the smaller forms of brush can be readily plowed without first removing the larger plants. Such land should be plowed deep, the larger growth afterwards removed and the surface thoroughly harrowed, graded, and smoothed. In plowing for the first time, 2 acres is a fair day's work for a man and three horses, and the cost of removing the larger plants seldom exceeds 50 cents an acre. Tracts which produce tall, coarse sagebrush from 3 to 5 feet high, in clumps from 4 to 8 feet apart, with more or less nutritious grasses growing in the open spaces, are more difficult to put in shape for irrigation. A serviceable homemade device formed of a railroad rail for the removal of sage brush is shown in figure 22. The methods used to remove native vegetation of this kind are discussed in Farmers' Bulletin 863, which can be obtained by applying to this department.

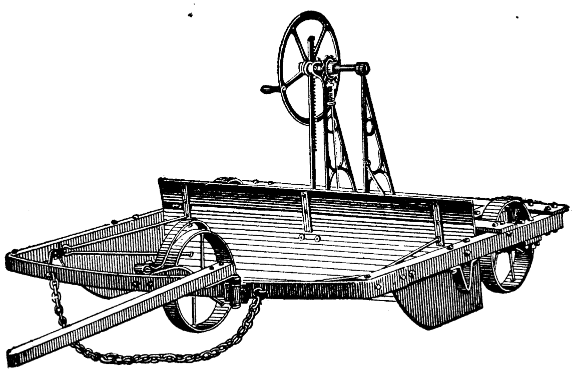

FIG. 15.—Grader.

Surface grading.—When land is covered with a heavy growth of sagebrush or when it is uneven, consisting of sand hummocks or heights and hollows, it is best not to attempt to complete the preparation of the surface the first season. The ground may be roughly prepared and seeded to grain or planted to potatoes. Later in the season it is irrigated as well as the nature of the surface will permit, and afterwards when the crop is removed it is thoroughly prepared for a permanent crop, like alfalfa. The roots of native grasses are then dead and the sagebrush roots interfere to a much less extent with scrapers, graders, and other farm implements. Besides, in the mountain States fields that are to be seeded to alfalfa should be prepared in the fall in order that the seed may be sown sufficiently early in the spring.

In the thorough preparation of a field for irrigation it is first plowed deeply and then graded with one of the implements commonly used for that purpose. Of these, the steel-shod drag shown on the title-page is one of the most serviceable. The manner in which the Fresno scraper is used to prepare land for the border

method of irrigation is shown in figure 23, p. 24. A modification of this scraper mounted on wheels and operated from a seat attached to the axle is illustrated in figure 24. This implement is made in three sizes. The smallest size is designed for a two-horse team, the medium for a three, and the largest for a four-horse team. Another implement for light grading is shown in figure 15. It consists of an

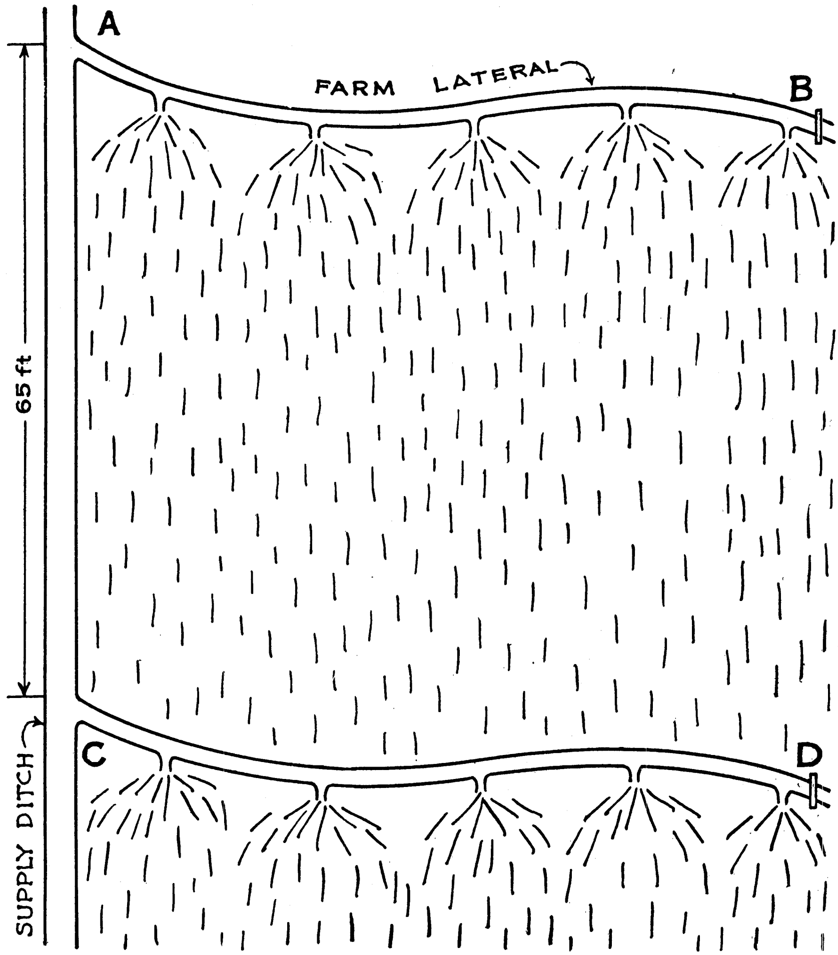

FIG. 16.—Flooding from field laterals.

oak frame attached to three low metal wheels and two steel-shod wooden runners. The steel cutting blade is $5\frac{1}{2}$ feet long, 20 inches wide, and curved. The blade is raised and lowered by means of a handwheel, and when a load of earth has been collected by cutting off the knolls, the implement is locked by the foot of the teamster and driven to the nearest low place where the load may be dumped

in a heap or scattered out in a thin layer. It takes two horses or mules to pull it in loose, granular soil, but three and occasionally four may be required in firm, hard soil.

Standard methods of preparing land for irrigation.—Many methods of applying water are used in western America, but the few herein described may be regarded as representative of all, the remainder being modifications of those named. A general knowledge of these is useful to the settler in that it enables him to compare their relative cost and efficiency, and assists him in deciding which is best suited to his conditions and to the size of his purse. His mind having been

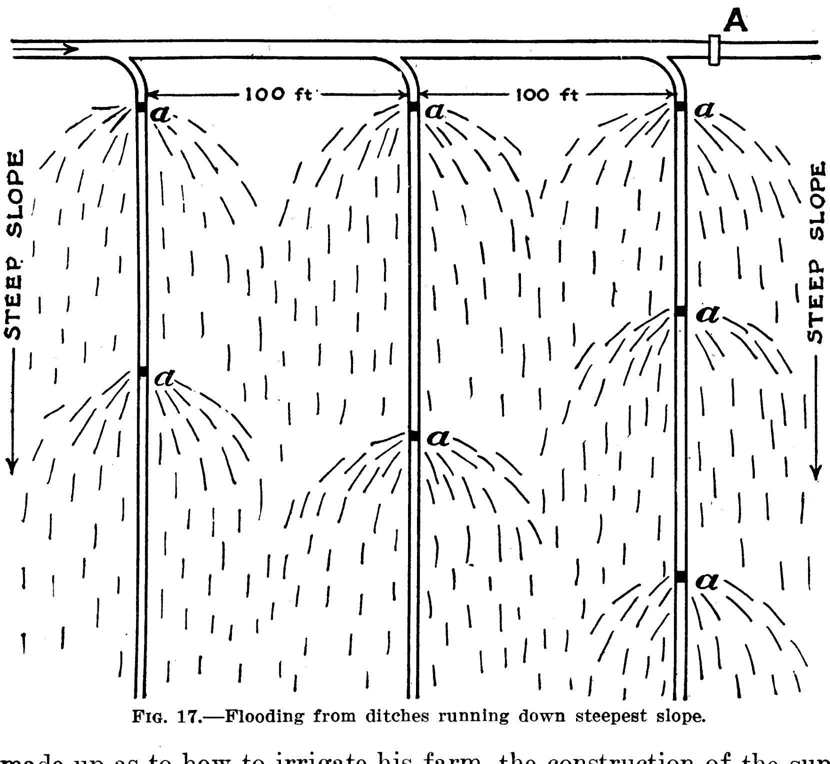

FIG. 17.—Flooding from ditches running down steepest slope.

made up as to how to irrigate his farm, the construction of the supply ditches and the preparation of the surface should conform to this method from the start.

Flooding from field laterals.—While flooding from field laterals is laborious and not the most effective method of irrigation, it is the most common. Probably 40 per cent of all the land irrigated in the West is still watered in this way. Its cheapness commends it to settlers of limited means. Besides, it is fairly well adapted to conditions such as are found in most of the mountain States where the land is often rolling and the most fertile soil shallow. Its use may be recom-

mended when the land to be irrigated is reasonably cheap, when the water is delivered in continuous streams or in small heads for given periods of time, when the members of the family can do the irrigating, when grain and forage crops are to be raised, and when a rotation of crops is desired.

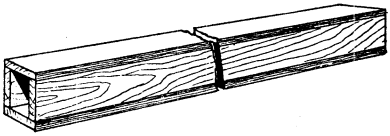

FIG. 18.—Lath pipe for ditch bank.

When a field has been leveled and graded, small ditches, called field laterals, are run through it. This work may be done either before or after seeding. On fields intended for alfalfa or meadows the laterals are made larger and with more care. Usually they are located on a grade of from one-half to three-fourths of an inch to the rod, and are spaced about 75 feet apart in grain fields, and about 90 feet apart in alfalfa fields. Sometimes the laterals extend down the steepest slope from the supply ditch. Figures 16 and 17 indicate these two methods of locating laterals. Small laterals may be made, with a common walking plow, but a lister or double moldboard plow attached to a sulky frame is to be preferred for medium-sized ditches. The larger laterals, designed to carry 4 or 5 cubic feet per second, may be made easily by riveting together two steel beam plows, one with a right and the other with a left-hand share. The manner of applying water to crops from field laterals is referred to on pages 34 and 36.

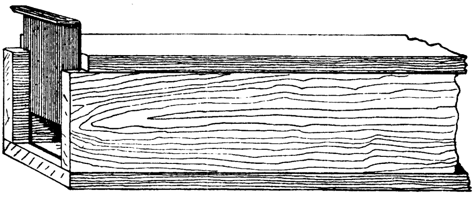

FIG. 19.—Pipe for ditch bank made from half-inch boards.

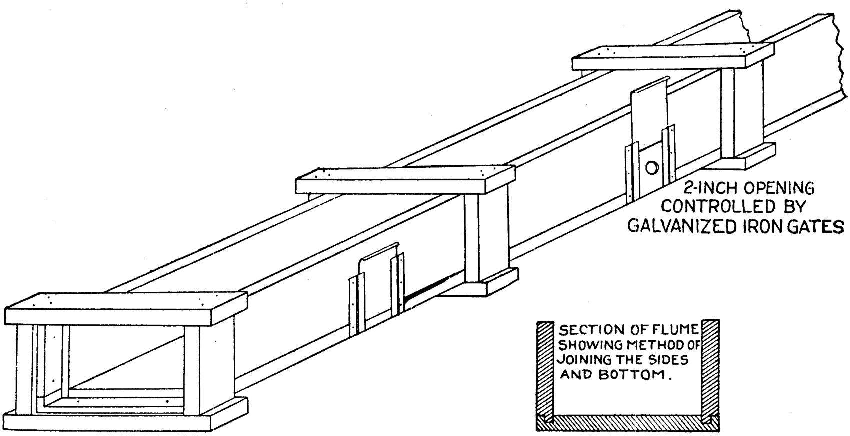

FIG. 20.—Wooden flume.

Furrow irrigation.—Nearly all crops that are planted in rows and cultivated are irrigated by means of furrows. This applies to such

crops as potatoes, sugar beets, corn, cotton, melons, vegetables, and fruit. The ground is first plowed, leveled, and graded in much the same way as that just described. The field is then divided so that each part can be watered readily from a head ditch. The distance between any two consecutive head ditches depends chiefly on the soil. In porous, sandy soils, furrows should not be more than 300 feet long. In soils which absorb water less freely, they may be from 400 to 1,000 feet long. These head ditches are fed from the main supply ditch of the farm, and usually are made after the field is partially leveled and graded.

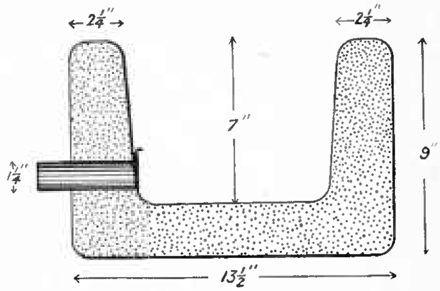

FIG. 21.—Cross section of 8-inch cement flume.

The chief difficulty in furrow irrigation is to divide the water in the head ditch somewhat equally among a large number of furrows. The irrigator may wish to turn water into 50 furrows at the same time, and unless he uses some device other than a shovelful of dirt taken out of the ditch bank the distribution will not be uniform. One of the best devices yet used for this purpose is a short pipe or spout, which may be made of wood. For small amounts of water

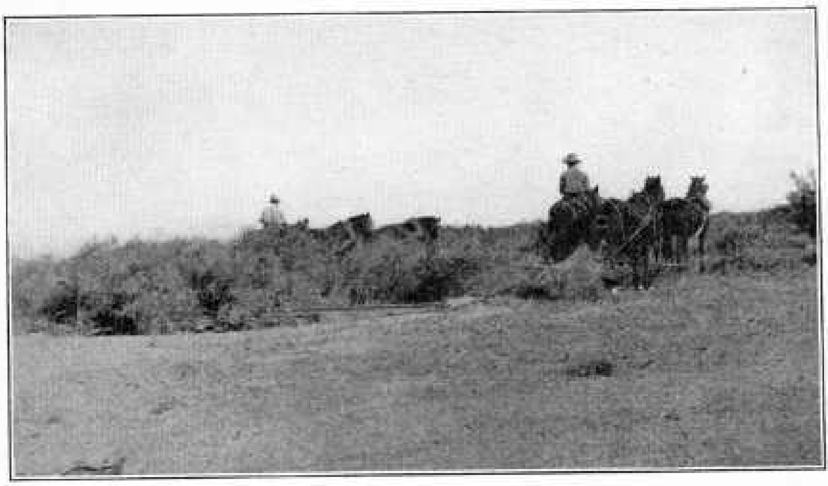

FIG. 22.—Clearing sagebrush with railroad rail.

less than 1 miner's inch, two pine laths cut in two, and the four pieces nailed together in the form of a pipe answer very well. For larger streams, requiring from 1 to 6 miner's inches, half-inch boards of the required width are used in place of the half laths. Figures 18 and 19 show these two forms of wooden spouts. A pipe is inserted in the

lower bank of the head ditch opposite each furrow. When this system is used, the head ditch should be divided into a series of levels by checks and drops, rather than have a uniform slope. In each level the pipes should be set at the same elevation, 2 or 3 inches below the water level.

Sometimes a small temporary head ditch is built just below the main supply ditch and parallel to it. From the former the water is distributed to the various furrows. In some localities where water is scarce and valuable, flumes and pipes of various kinds are used to convey and distribute the water to furrows. In others the distribution is accomplished by a system of temporary head ditches

FIG. 23.—Preparing land for border irrigation with a Fresno scraper.

parallel to the main ditch. A sketch of a distributing flume built of wood is given in figure 20 and one of cement concrete in figure 21.

Head flumes of either wood or concrete, being placed on the surface of the ground, interfere greatly with the free passage of teams and implements in cultivating, irrigating, and harvesting the crop. Dead leaves from shade and orchard trees also clog the small openings in the flumes. The space on each side of the flume is likewise a breeder of weeds, the seeds of which are carried in the open channel. These and other objections to flumes have induced many orchardists to convey and distribute the water in underground pipes. Descriptions of pipes and distributors suitable for this purpose are given in Farmers' Bulletin 882 and Department Bulletin 906.

A field having been laid out in the proper manner as regards head ditches, and some effective way provided of getting the same amount of water into each furrow, the only important thing remaining to be done is to grade the tracts properly between the ditches. This should be well done in order to allow a small stream to flow down

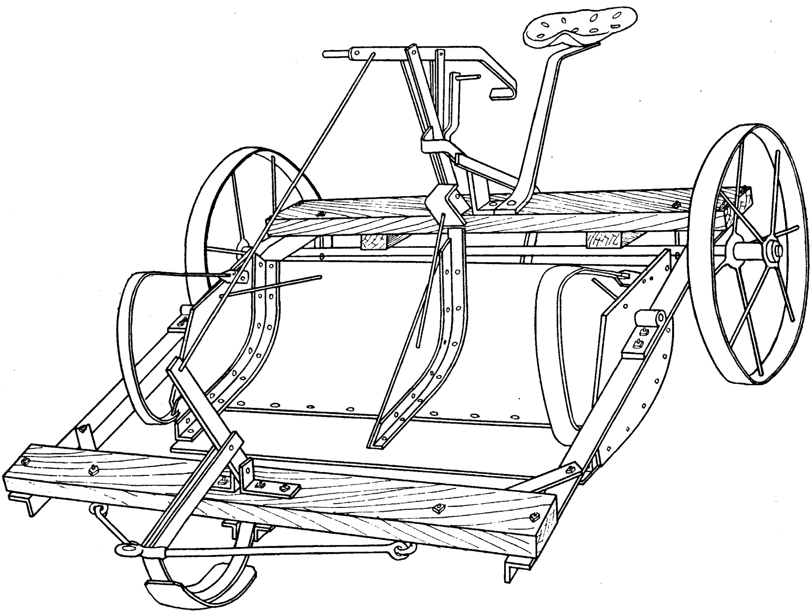

FIG. 24.—An improved scraper extensively used in Idaho and other States.

each furrow. The implements already referred to will grade the surface properly.

Check irrigation.—The check method of irrigation is confined mainly to alfalfa. It consists in dividing up a field in contour or rectangular checks each comprising, as a rule, from one-half acre

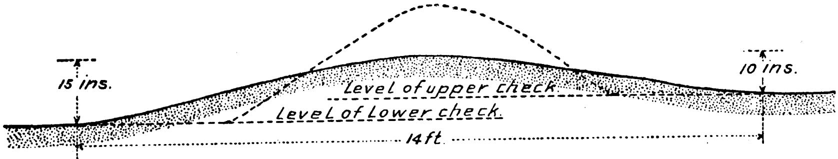

FIG. 25.—Low and broad check levee.

to $1\frac{1}{2}$ acres. Around the margin of each check a low embankment or levee is formed which retains the water until it has been absorbed by the soil. The manner of laying out and building the checks has been fully described in Farmers' Bulletin 865.

The field to be checked is first laid out in contour lines—lines connecting points of equal elevation—the difference in level between any

two lines being from 3 to 6 inches or more, depending on the slope. With 3-inch contours on land which slopes 8 feet to the mile, the contour lines would be about 160 feet apart. On steeper slopes this space is decreased and the elevation between adjacent contours increased. Land which slopes 50 feet or more to the mile is not suited to check irrigation. The contours may be located by the use of an engineer's level and rod, or by the homemade level already described (p. 17). When the contour lines are run the intervening spaces are subdivided by cross levees into areas containing on an average about three-fourths acre. Provision is also made at this time for field

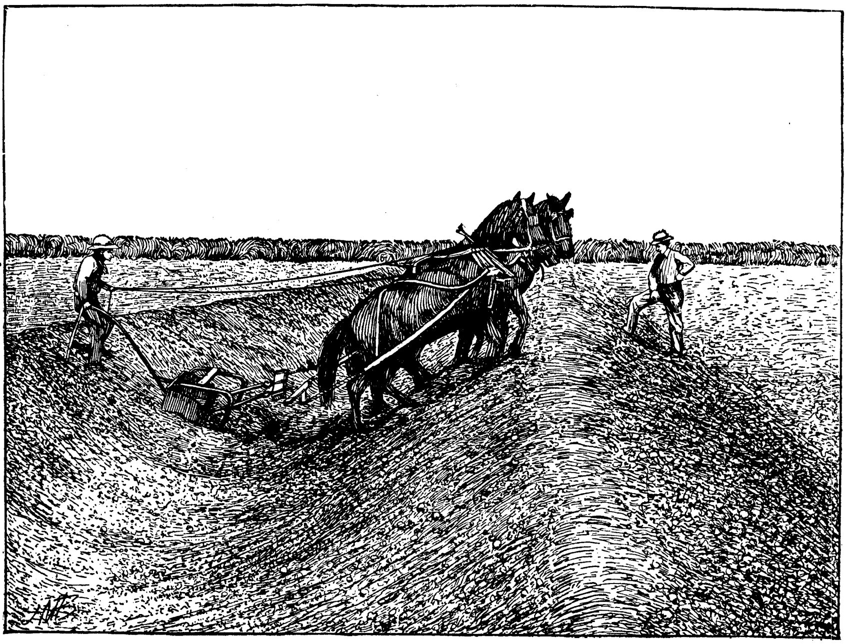

FIG. 26.—Constructing lateral ditch with scraper.

ditches to convey water to each check. After temporary stakes are set to mark the corners of the checks, a plow furrow is run around the margin of each so as to mark it permanently. This being done, portions of the field may be checked whenever the farmer has time. Many farmers prefer rectangular to contour checks. In laying out these, contour lines are run and the rectangular checks are fitted into the spaces in such a way as to require the moving of the least possible volume of earth. Such checks cost more, but they are more convenient for farming operations.

In building the levees around checks a scraper drawn by two or three horses or mules is generally used. All knolls and hummocks within the check are first scraped down and the earth placed in the

levee. If more dirt is needed, the high corner or end of each check is removed, leaving the floor fairly level, or with a slight grade away from the check box where the water is admitted. Levees are also made by plowing twice across and back along the line, and crowding the earth into the levees by means of a V crowder. (Fig. 5, p. 11.) The field is then plowed, harrowed, and seeded in the usual way. Levees when first built are too high and steep, but with the subsequent plowing, harrowing, and settling they should become similar to figure 25 about the time the first crop of alfalfa is ready to cut. The dotted line in figure 25 represents the general shape of the levee when first formed.

A ditch is built to carry water to each check or pair of checks. The capacity of these should be fully equal to the head used, which in California is about 10 cubic feet per second. The shape of such a ditch in course of construction is shown in figure 26. Each check should be provided with a box controlled by a gate. These boxes are made of wood or concrete. A wooden box of the common type is represented in figure 27.

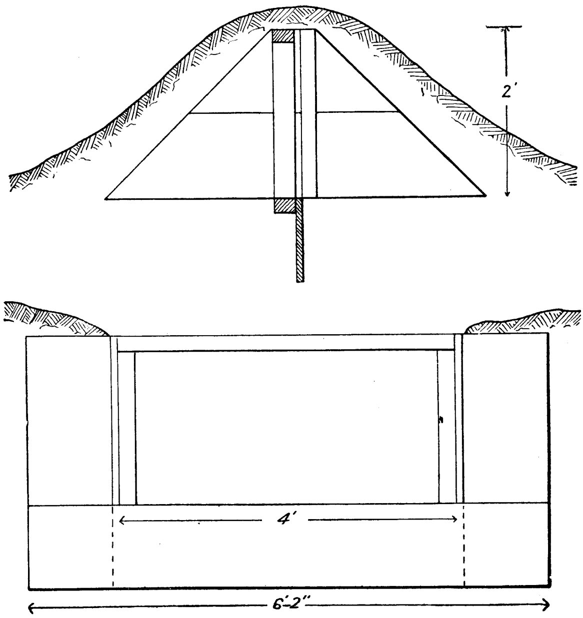

Fig. 27.—Check box, showing section across embankment at top and lengthwise of bank at bottom.

Border irrigation.—In preparing land for border irrigation, it is first plowed and then divided off into a number of parallel strips which extend down the steepest slope. The widths and lengths of these strips should conform to the nature of the soil, the quantity of water available, the slope of the land, and other factors. In sandy or gravelly soils that absorb water readily, the length should not exceed 330 feet and the width 25 feet. In ordinary loam soils, the usual dimensions are 30 to 40 feet wide and 400 to 600 feet long; in compact soils or in loam soils having compact subsoils, the length may be increased to 1,000 feet and the width to 50 feet.

After the location of the various borders has been marked by a plow furrow, teams hitched to scrapers cross and recross the field, re-

moving earth from the high places and depositing it on each border in passing. This operation is similar to raking hay into windrows. Borders made in this way are irregular with too steep slopes; but by harrowing crosswise and lengthwise they can be made reasonably straight and rounding so as to confine the water within each pair and at the same time permit the easy passage of mowers, reapers, and other implements. The space between borders should be made level and smooth. If it is not level the water will collect on the low side and if the surface is not smooth the water will be retarded in its flow and distributed unevenly. A portion of a field prepared for this method of irrigation is shown in figure 28.

FIG. 28.—Field prepared for border irrigation.

The head ditch which furnishes water to each strip in turn or to two or more strips at the same time is located on a proper grade along the upper edge of the field. The water is checked in this ditch by a canvas dam or permanent structure and one or more border gates opened to admit water into the strips.

Instead of having head ditches in earth, pipes are sometimes used to conduct the water to the several strips. In such cases valves set in low strands take the place of the gates shown in figures 29 and 30. One of these to which is attached a piece of canvas tubing to aid in distributing the water without eroding sandy soil, is shown in figure 31.

PREPARING LAND FOR GARDEN IRRIGATION.

For obvious reasons the farm garden which is intended for growing small fruits and vegetables for home use should be located as near to the farm buildings as possible. The next factors in importance are suitable soil and an ample water supply, readily obtainable. As regards soil, a well-drained loam is the best for an irrigated garden. Soils which are naturally either too heavy or too light for such purpose can be much improved by proper treatment. For adobe soils Prof. Wickson, former director of the California Experiment Station, recommends the use of air-slaked lime, deep and thorough tillage, and the plowing in of as much coarse material as possible. "Farmyard manure," he states, "straw, sand, old plaster, coal ashes, sawdust, almost anything coarse or gritty which will break up the close adherence of the fine clay particles, release the surplus water, and let in the air, will produce a marked effect in reducing the hateful baking and cracking, root-tearing, and moisture-losing behavior of the adobe."[1] For improving a light sandy soil the same author recommends the use of plenty of well composted and decayed manure.

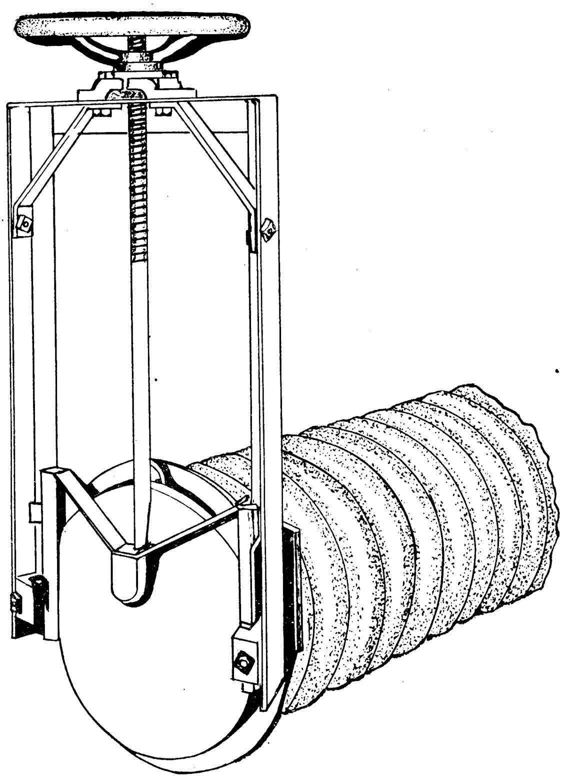

FIG. 29.—Valve for use on canals and small reservoirs.

The water supply.—The water supply for the garden should be taken from the main supply ditch, as shown in figure 31, or it should be derived from an independent system. The latter may consist of a small pipe laid from some near-by spring or creek and connected with a tank or reservoir near the ranch buildings. When water can not be conveyed by gravity it is often raised from wells by means

[1] California Vegetables in Garden and Field. By E. J. Wickson, p. 49.

of a small pump operated by an electric motor, gasoline engine, or windmill. These small independent systems should furnish sufficient water for domestic purposes, for the use of stock, and for the irrigation of a small fruit and vegetable garden.

A plan for an irrigated garden.—Gardens for home use in irrigated districts should be laid out in such a way that the bulk of the work can be done by teams and in the easiest way. It is doubtful if the laborious methods practiced by the Asiatic and Latin races in cultivating by hand, in the use of raised or depressed beds, and in seasonal rotation of crops will ever become popular with American farmers in irrigated districts. Figure 32 shows the outline of an irrigated garden which is intended to provide the farm home with an abundant supply of fresh fruits and vegetables for the table, and freshly cut alfalfa for poultry, a few pigs, and for a cow part of the time, at the least possible amount of manual labor and trouble. The tract contains $1\frac{3}{4}$ acres, being 440 feet long and 170 feet wide, between woven-wire fences. The main supply ditch of the farm and a lane or public road extend along one side and the farm buildings abut it on another. A head ditch or flume taps the supply ditch and extends across the upper end. The garden is divided into three parts, the small fruits and other perennials being planted at the far side, the vegetables next, and a strip of alfalfa of the same size as that occupied by the vegetables next to the fence. This provides, when desired, a convenient rotation. At the end of two or three years the strip of alfalfa or clover may be plowed under in the fall and vegetables planted the following spring. The plat first planted to vegetables may then be plowed and prepared for irrigation in the manner described under the border method of irrigation and seeded to alfalfa or clover. There is also a strip 15 feet wide at the upper end of the garden seeded to alfalfa or clover. On this the teams turn in cultivating between the

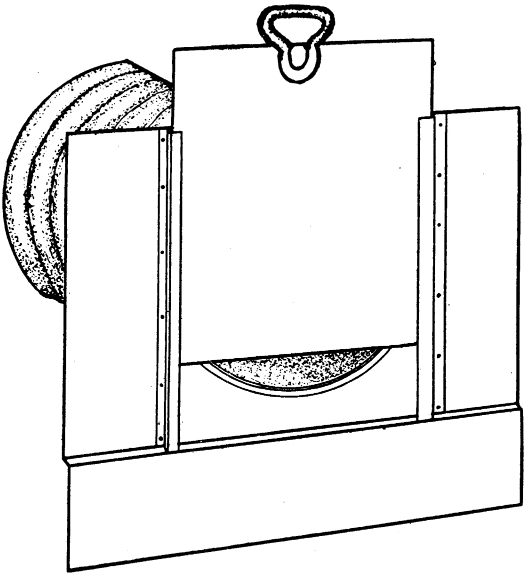

FIG. 30.—Headgate set in low stand for use in small ditches.

rows. There is a like strip in forage crops at the foot of the garden which serves the same purpose and also utilizes the waste water which is apt to escape from the furrows. In order to serve this twofold purpose it is made 25 feet wide. In case a two years' rotation of crops between the vegetables and alfalfa or clover is not considered necessary or desirable, the garden may be made longer and narrower and the lower portion seeded to alfalfa to be retained permanently.

IRRIGATING DIFFERENT CROPS.

ALFALFA.

Preparation of soil and sowing.—Alfalfa is irrigated most commonly by being flooded from field laterals. In certain localities it is irri-

FIG. 31.—Canvas tubing attached to a metal valve for distributing water in border irrigation.

gated by borders, in others by checks, and in a few localities by furrows. Sowing alfalfa seed with a nurse crop like oats or wheat was more common 15 years ago than it is at present. The prevailing usage now, except in Utah and parts of Colorado, is to sow only alfalfa seed. The soil should be thoroughly prepared. This holds true for each of the methods of irrigation described. Alfalfa is a tender plant for the first few months of its growth and requires favorable conditions. The soil when the seed is sown should contain sufficient moisture to nourish the plant until it is several inches high and covers the ground fairly well. In the colder and higher States of the West the necessary moisture may be secured by preparing the fields the previous fall and permitting the deeply plowed land to

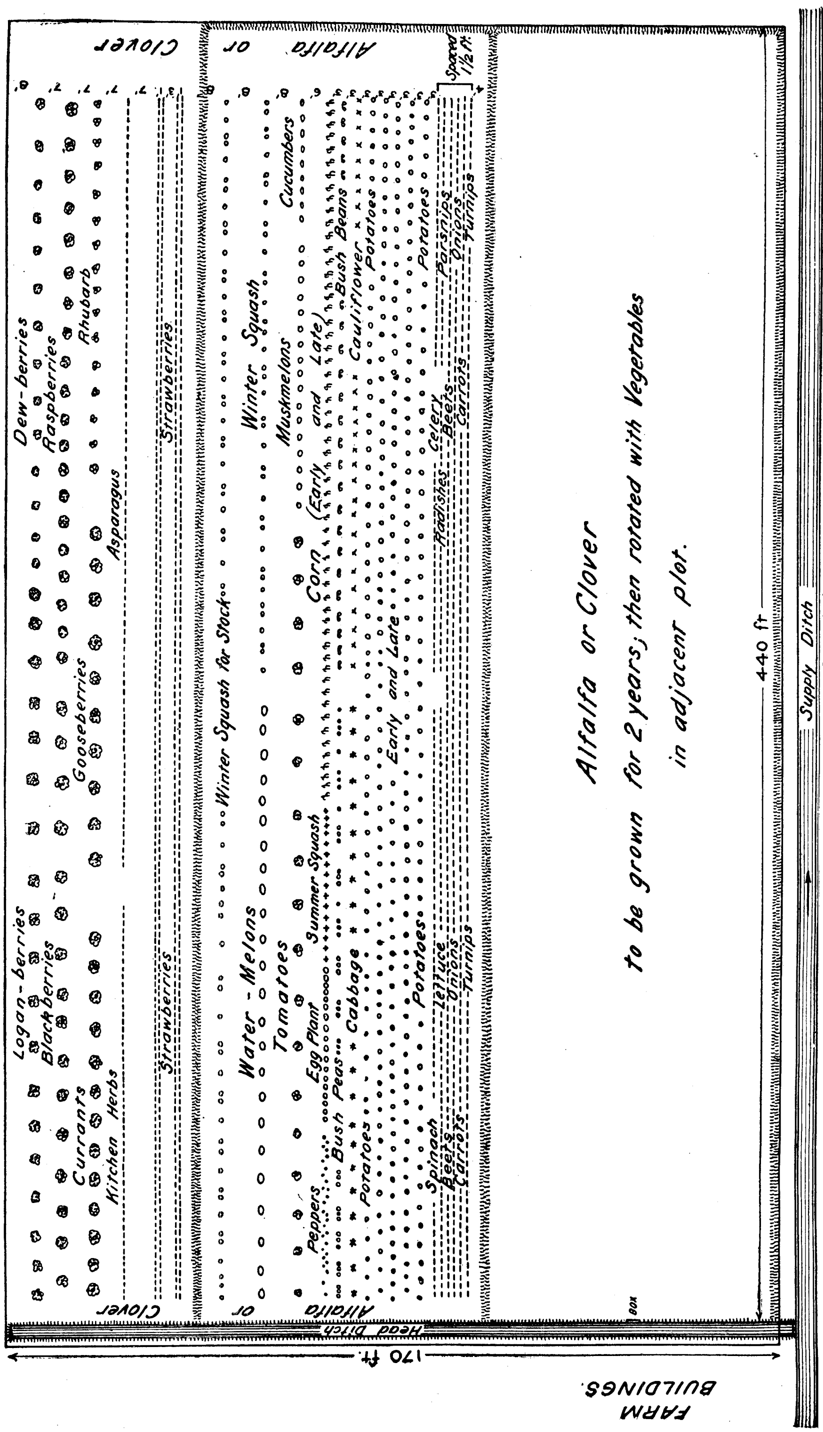

FIG. 32.—Plan of irrigated garden.

absorb a large part of the rainfall and snowfall. Then, in the spring, as early as the ground is fit to work, it is again cultivated, after which the seed is sown. In the warmer States, likewise, the fields are prepared in the fall, but instead of depending on rain from passing clouds the soil is well irrigated, and this added moisture sinks deep into the soil, which is subsequently cultivated and seeded. In the Southwest fall seeding is practiced. This prevents to a considerable extent the trouble usually had with weeds in the first crop.

Early irrigation of crop.—If skill is used in providing an ample supply of moisture before the seed is sown there will be no need of early irrigation. Mistakes are frequently made by sowing the seed

FIG. 33.—Making earth checks in a field lateral.

on too dry soil and then applying water at frequent intervals when the plant is young. This practice causes the roots to branch out near the surface and to depend for food and moisture on the top layers of soil, which are subjected to extremes of drought and moisture. When the soil is fairly moist at time of planting and the surface is thoroughly cultivated, so as to retain the moisture, there will be no need of applying more until the crop shades the ground. Meanwhile the alfalfa may suffer slightly, the leaves, and even the stems, may become brown, but in its effort to survive by getting moisture it will extend its taproot far down into the subsoil. Forcing the plant to hunt for moisture from beneath and keeping the surface layer dry and well pulverized, without any crusting or baking, pro-

duces a fine root development which will not be affected by the alternate droughts and saturations of the surface layers.

Irrigation by flooding.—In irrigating alfalfa by flooding, field laterals are run out from the head ditch 75 to 100 feet apart on a grade of one-half to three-fourths of an inch to the rod, or from 3 to 4½ inches fall in each 100 feet. These laterals are large enough to carry the head used, which may vary from 1 to 3 cubic feet per second, and should be made at the time the crop is planted. One irrigator can attend to two streams which are kept running in adjacent laterals. At given distances, varying from 75 to 150 feet, he places some temporary dam in the channel, which stops the flow in that direction and causes the water to flow over low places in the bank. The dam used may be of canvas or metal, or it may consist of a pile of earth formed by the implement shown in fig. 33. If the seed drill has been run in the direction which the water takes after leaving the laterals it will help to distribute the water evenly and quickly. The water is allowed to run until the upper foot of the soil is saturated, any excess which runs off being caught by the lower lateral. By this method one man in 10 hours will irrigate from 2 to 4 acres, depending on the character of the soil and the size of stream used.

Irrigation by the check system.—When the land is checked, the labor and expense of irrigating are much reduced. A large head of water is used, which is turned into a check by simply raising a wooden gate. When sufficient water has been admitted, a gate to the next check is opened and the first one closed. Two men in 12-hour shifts should irrigate, on an average, 15 acres per day.

Irrigation by the border method.—In irrigating by the border method water is turned into the head of each strip and flows over the surface in a thin sheet. Experience will show the farmer how long to permit the water to flow on each strip, but the time will depend on the character of the soil. Heavy clay should have water kept on the surface for some time as it absorbs water slowly; while sandy soils should be irrigated quickly in order that the water shall not be lost by deep percolation.

Furrow irrigation.—Some soils can not be successfully irrigated by flooding or in checks, for the reason that very light soils wash when flooded and a crust forms on the surface of other soils after each wetting. When alfalfa is grown on soils that bake, it usually is watered by furrows. These furrows are from 3 to 6 inches deep and from 2 to 4 feet apart. Each furrow is fed by a wooden spout placed in the head ditch (p. 23). The cost of irrigating by this method is about the same as by flooding from field laterals.

Irrigating with portable pipe.—In southern California, where water is scarce and the cost is high, so that waste is a serious matter, water

is distributed on the fields through portable, slip-joint pipe. Pipe is laid from the head ditch or pipe down the field, and water is discharged at the exact point to be watered by adding or removing joints of pipe. When one strip down a field has been watered, the pipe is moved to an adjoining strip and the process is repeated. This method is adapted especially to very light soils where a large part of the water would be lost by seepage if it was run over the surface or in open ditches for any considerable distance. This method is more expensive than the others described, for both equipment and labor.

Irrigation after first crop.—In many sections the rainfall during the spring months supplies sufficient moisture for the first crop. Each subsequent crop is irrigated once, as a rule. Opinions differ as to the proper time to irrigate. The custom in the Yellowstone Valley, Mont., is to irrigate the land before the crop is cut. The grower decides upon a date a week or 10 days in advance when his alfalfa will be ready to cut. He likewise estimates the number of days it will require the soil to dry out sufficiently after an irrigation to enable the mower and wagon to pass over the surface without any injury to the field or the next crop. Accordingly, the field is first watered and then the crop is cut and stacked. The custom in Utah and New Mexico is to harvest the crop first and then apply water to the stubble. What would be good practice in one locality might be bad practice in another. The size of the farm has much to do with the case. On small farms the crop may be removed in the forenoon and the water applied in the afternoon. On large farms several days may intervene, and by that time the stubble is withered to such an extent that it may take a week to restore the lost vigor of the crop. This condition may be guarded against by watering before cutting and again as soon as the crop is removed. The main thing to keep in mind is the necessity of keeping the plant growing vigorously all the time. Any practice which checks the growth should be modified.

GRAIN.

Method of irrigation.—Grain fields usually are irrigated by flooding from field laterals. Furrow irrigation is practiced only where the soil bakes after being flooded. The border method of grain irrigation is gaining over the other methods. The most of the irrigated grain is raised in the mountain States in rotation with a leguminous crop, like alfalfa or clover. In some localities potatoes or beets form a part of the rotation. In rotating with cereals and legumes, or with cereals, legumes, and roots, the flooding and border methods are readily adapted to each kind of crop. This accounts in part, at least, for their general adoption in most irrigated districts.

Preparation of the land.—As a rule, the land should be plowed in fall and seeded as early as possible the following spring. The time of

plowing is determined largely by the rainfall and the fitness of the soil. The time of seeding is likewise determined by these same conditions, and also by the occurrence of frosts. In the Southwest grain is seeded in the fall and harvested in the late spring, and is sometimes followed by a corn crop. The methods employed in grading and leveling are similar to those previously described. When the grain is from 4 to 6 inches high, the field laterals are run out. These extend on grade lines from the head ditch and are spaced 60 to 70 feet apart. If the surface has been well prepared, a grade of one-half inch to the rod will be ample for the laterals. On less even ground the grade should be increased to three-fourths of an inch or more per rod. Each lateral should be made large enough to carry about 1 cubic foot per second. An irrigation stream of 2 to 3 cubic feet per second may be divided equally between two laterals, and one of 3 to 4 cubic feet per second between three laterals. In the plan shown in figure 16, page 20, the stream is divided between two laterals, A–B and C–D. The flow in A–B is checked at B and in C–D at D. The checks used at B and D may be canvas dams, metal tappoons, or manure heaps faced with earth on the upstream side. When the space between A–B and C–D is watered, the check dams at B and D are removed and placed in a similar manner 75 feet lower down. This operation is continued until the entire field is irrigated.

When to irrigate.—No fixed rule can be laid down for the proper time to irrigate grain. The soil should contain sufficient moisture at seed time to nourish the crop until it shades the ground. A quantity of water varying from 4 to 9 inches in depth over the surface, depending on the character of the soil, may then be applied at one irrigation. A second irrigation usually is applied when the grain is beginning to head out. This seems to be the critical period in the irrigation of grain. The plants are using at this time the maximum amount of moisture, and as soon as there is a deficiency they begin to suffer. When the growth is checked at this stage, the lost vigor can not be wholly restored by subsequent watering, and the yield is lessened. The amount of water required by cereals during the first six weeks of their growth is small, if one excepts the heavy loss by evaporation from the surface of newly cultivated and seeded fields. The amount of water required during the last three weeks of growth is likewise small. The number of irrigations during the intermediate period of 40 to 60 days varies from one to four, depending on local conditions. After the last irrigation has been applied the banks of the field laterals are leveled with a small walking plow drawn by one horse. The field is then ready to harvest.

POTATOES.

System of irrigation employed.—Potatoes and other root crops are irrigated by furrows made midway between the rows. These furrows should not be over 600 feet long, and in light sandy soils with little fall this distance should be reduced. The length of the furrows may be readily shortened by putting in more head ditches. Short furrows insure a more even distribution of water, and frequently prevent injury to the crop by the water-logging of a part of the soil.

A well-drained, sandy, or gravelly loam, rich in decayed vegetable matter, is the best for this crop. If the soil is wanting in organic matter it should be supplied by the right kind of a crop rotation. In Colorado a common practice in raising potatoes is to grow alfalfa for two years, then plant to potatoes for two years, and at the beginning of the fifth year seed to wheat and alfalfa. In turning down alfalfa in the spring before planting potatoes, the field should first be irrigated and afterwards plowed from 6 to 8 inches deep when the soil is dry enough to crumble into small particles as it falls from the moldboard.

Potatoes grown on irrigated land are not the best for seed. They seem to be more subject to disease. Smooth round tubers, free from disease, and grown on nonirrigated land, should be planted 30 to 42 inches apart and 3 to 6 inches deep. The soil is well cultivated between the rows and the whole surface harrowed before the potatoes come up. During the first stages of growth cultivation is the essential thing. If the ground has been irrigated before planting, one heavy irrigation at the time the tubers are beginning to form may be sufficient. In other cases from two to four waterings may be required. The important thing to remember is to keep the top layer of soil well pulverized by frequent cultivations and to supply enough water to produce moist soil beneath this surface mulch. The amount of moisture in the soil around the roots should be kept as nearly uniform as possible, except when the tubers are beginning to form, when it should be increased, since this is the critical stage in the life of the plant and more water is required.

Irrigation practice.—The most common mistake in the irrigation of potatoes is to turn a large head in each furrow, permit it to flow rapidly to the bottom of the rows, and then shut it off. This way of applying the water wets only the surface layer, and if it is not followed up immediately by cultivation a couple of days of sunshine will rob the soil of most of the water which has been applied and seal over the surface with a hard crust. In this condition the crops soon begin to suffer, and the unskilled farmer fancies that the only remedy lies in applying more water. A better plan is to turn only a small amount of water into a deep furrow and permit it to run without

stopping for hours or even for half a day. In this way the top layer is not saturated, the soil around the roots and beneath them receives a larger supply, and the surface may be cultivated shortly after each irrigation, so as to check evaporation and retain the moisture in the soil for the benefit of the crop.

FRUIT TREES.[1]

Planting for irrigation.—According to Prof. Wickson, of the California Experiment Station, apple trees should be planted on an average about 28 feet apart; cherry, plum, prune, apricot, peach, pear, and olive trees about 24 feet apart, and citrus trees 20 feet apart. On ordinary slopes, from 10 to 100 feet to the mile, the trees may be planted in rows down the steepest slope. Where the ground is so steep that water flowing in furrows will scour the bottom, the tree rows should extend diagonally across the slope so as to lessen the grade. On rolling ground the trees should be planted on grade lines so as to conform to the natural surface and render easy the task of applying water.

Irrigating.—The most common method of irrigating fruit trees in western America is by furrows from 500 to 600 feet long. There is, however, a wide difference in practice in the distribution of water from the supply ditch to the head of each furrow. This is done in the mountain States by making openings in the ditch bank with a shovel opposite each furrow. While this is the cheapest method it is not the best, because one can not divide the head evenly among the furrows, and as a rule the greater number receive far too much water. When 5 or 6 miner's inches are turned into a furrow on a fairly steep slope the part which is not absorbed soon flows down to the end where it is wasted. The passage of this stream for a short time saturates only the top soil, which will afterwards crust over to the injury of the trees and the loss of water by evaporation. Some device resembling the wooden spout previously described (p. 23) should be used to regulate the flow, and excepting in sandy soil permit only a small stream to flow in the bottom of each furrow for a much longer period. In localities where water is valuable the earthen head ditch is seldom used. Water is distributed to the furrows through small openings in wooden flumes (fig. 20) or else through similar openings in cement flumes (fig. 21). At the present time concrete pipes and sewer pipes, as well as metal pipes, are quite extensively used in the citrus orchards of California for this purpose.

The length of the irrigation season varies from one to twelve months, according to the rainfall, temperature, crop, etc. Young

[1] The methods of irrigating orchards are treated more fully in Farmers' Bulletin 882.

trees are watered by a furrow on each side of the row and, as the trees grow older and larger, the number of furrows is increased until all the space between the rows is watered. The idea to be kept in mind is to train the roots outward and downward so as to enlarge their feeding zone. The best guide to successful practice is to make frequent excavations to find out not only the location of the roots but also how far and in which directions the water from the furrows has percolated. The perfect way of watering fruit trees would be to keep the surface dry, not disturb the dust mulch, and apply the water beneath. This is not practicable, but the skillful irrigator can approach this ideal practice by making deep furrows, using a small stream in each, and letting it run for a long enough time.

SMALL FRUITS AND VEGETABLES.

The small fruits and vegetables included in the farmer's garden, of which an outline is shown in figure 32, page 32, are arranged so that the crops which require similar treatment in the way of spacing, cultivating, and irrigating are placed in the same row or in bordering rows.

Loganberries and dewberries occupy the first row. These are planted 3 to 4 inches deep and 4 feet apart in the row, with a space of 7 feet between the rows. They are irrigated by a small furrow on each side of the row, and the soil is well cultivated after each irrigation. The vines are cut back after the first year's growth, and in the following spring a low, flat ridge is formed to keep the irrigation water from wetting the vines and fruit.

Blackberries and raspberries are set out in a deep trench, 4 and 3 feet apart, respectively. For the first season the water in irrigating will follow this trench. In subsequent seasons it should be applied in furrows between the rows.

The cuttings of currants and gooseberries are taken from the nursery or from the parent bush and set out about 6 inches deep and 3 feet apart. The water is applied in furrows which are run near the plants the first season. In subsequent seasons all the space between the rows is moistened by running water in two furrows and cultivating afterwards.

Asparagus roots when taken from the seed bed are planted about 2 feet apart in a trench enriched with well-rotted manure. They are covered with fine loam 3 inches deep, and as the plants grow more fine loam is placed around the roots until the trench is filled. The first waterings may be applied in the trench and afterwards from one or two furrows in the open space.

Squash, melons, cucumbers, tomatoes, corn, and cabbage are planted in the usual way on soil which should be adapted in texture

and richness to each variety. The standard method of irrigating these crops is by furrows run between the rows. In making the furrows and applying the water the main purpose kept in view is to moisten the soil uniformly to the required depth without wetting the vegetables and with the least possible wetting of the surface. This can be accomplished by planting the seed at the water's edge in the furrows and training the plants on the area between furrows.

For convenience in irrigating a garden the head ditch should be a wooden flume with holes in the side to admit water to each furrow. Those who can not afford the expense of a flume should insert small wooden spouts (fig. 19) in the lower bank of the head ditch, opposite the furrow spaces, as suggested on page 23.

Plant like carrots, beets, turnips, etc., which are planted in rows 18 inches apart and cultivated by hand, may be all watered at one time in the following manner: A stream of about 6 miner's inches may be taken from the head ditch and conducted along one border. This stream may be divided into three small heads, one-third being used to irrigate the upper part of the strip of ground devoted to these vegetables (fig. 32), the other applied to the middle part, and the balance to the lower part. By this arrangement about 2 miner's inches are divided up among five rows, which are shortened to 133 feet. Any waste water which collects at the foot of each division may be led into the main furrows at the edge of the field.

HOW TO LESSEN THE WASTE OF WATER.

Loss by absorption and seepage.—The quantity of water which plants use forms but a small part of that which is diverted from streams for irrigation purposes. Large volumes are lost by absorption and seepage in the earthen channels of canal systems. Similar losses occur in the ditches which supply farms, and a large part of the remainder is wasted in irrigating crops. The farmer is chiefly concerned in lessening the waste of water in his supply ditch and on his farm. In localities where water is scarce the supply ditch should be made water-tight. This may be done by lining the channel with cement concrete, cement plaster, asphalt, heavy crude oil, or clay puddle. Flumes or pipes may also be used as a substitute for an earthen ditch.

Loss from faulty preparation of surface.—One of the most common sources of loss of water is poor preparation of the surface. When the soil is irrigated by flooding from field laterals an uneven surface causes needless waste of water, extra labor in spreading it over the surface, and smaller yields. The water flows into the low places, which receive too much and may become water-logged, while the high places are left without water and the crop thereon is dwarfed. The

surface between field laterals should be so evenly graded that water will flow in a thin sheet over the entire surface, the excess being caught up by the lower lateral.

Loss from neglect.—Another common cause of waste is the lack of attendance. Water is often turned on a portion of a field and permitted to run without attention for hours and even days. On some farms the irrigators look after the water for 10 hours and turn it loose for the balance of the day. Under this practice the low places receive too much, the high places little or none, and a large part flows off the field to the injury of the roads and adjoining farms.

Inefficient irrigation.—Too shallow and too frequent irrigation is another source of waste. Wetting the surface and neglecting to cultivate it afterwards may result in the loss by evaporation of three-fourths of the water which is applied in this way. For most plants, and for all deep-rooted plants in particular, the ground should be so prepared that water would readily percolate to a considerable depth beneath the surface and enough water should be applied to moisten the subsoil. However, light, open soils retain but little moisture, and with such soils light, frequent irrigations are necessary.

RIGHT QUANTITY OF WATER TO APPLY.

The amount of water to apply in one irrigation, the length of the interval between irrigations, and the total quantity used in any one season all depend on a large number of soil, crop, and climatic conditions. The limited space will not permit these to be fully considered. Accordingly, only those features which seem to be of greatest interest to the irrigator are touched upon.

PROPER PERCENTAGE OF SOIL MOISTURE.

Why irrigation is practiced.—The main purpose of irrigation is to furnish the requisite amount of moisture to cropped soil. Too little, as well as too much, moisture in soils injures plants, and it is not easy to find out how much is best for each kind of soil and for each kind of crop. About three-fifths of the volume of clay soils and two-fifths of sandy soils is open space, while the loams range between. The greater part of the water found in the open space furnishes moisture to the roots of plants; the remainder clings to the soil particles and requires a considerable amount of heat to drive it off in the form of vapor. The irrigator need concern himself with the former only, which is known as the free water in the soil, since it nourishes his crops. One of the first questions which confronts the irrigator is to know how much of this free-water soils should contain in order to produce a vigorous growth. The answer in general terms is, about 1 pound of free water to 10 pounds of soil as it is taken from a field.

Percentage of soil moisture.—Farmers in irrigated districts can find out for themselves the proper percentage of soil moisture. All that is necessary is a soil auger and a balance scale to weigh the samples. The price of the scale will vary from $3 to $5 and that of a suitable auger from $1 to $2.50. The samples should be taken from the soil around the roots of the cultivated plants. If these roots extend from 6 inches to 4 feet below the surface, then the sample should be an average of this 42-inch layer or else separate samples should be taken at various depths. The sample of earth should be immediately placed in a glass fruit jar and the cover screwed down tight on a rubber band. The sample is afterwards weighed by taking an even number of ounces. Assume that 100 ounces is the weight before drying, and that after the sample is spread out thin over a tin pan and exposed to the sun for the greater part of a day it weighs only 90 ounces, this would indicate that there is 1 ounce of free water for every 10 ounces of moist soil. It will be found that a balance which weighs in grams will be more convenient. Thus if weights equal to 100 grams are placed in one pan and balanced with a part of the sample of soil in the other pan, and if the same after being thoroughly sun dried weighs 96 grams, it would indicate that there was only about 4 per cent of free moisture in the soil, and that the field required to be irrigated. If the sun-dried sample weighed about 90 grams, it would show that there was sufficient moisture for rapid growth, and if it weighed only 86 grams it would indicate an excess of moisture.

Quantity of moisture required to give best results.—The rule given above may serve as a guide to the beginner in irrigation during the first season. After that he should ascertain for himself the percentage of free moisture which will give the best results. This may be done by taking samples of soil from fields on which crops are doing well. It may happen that in sandy land the amount of free moisture found in the soil, around the roots of potato vines, for instance, is only 6 per cent. If the crop shows no signs of suffering for lack of moisture, it may be taken for granted that this percentage is sufficient. On the other hand, if in weighing samples of soil taken from the upper 4 feet of an alfalfa field in good condition and consisting of clay loam 20 per cent of free moisture is found, it may be inferred that the extra amount is required.

Moisture not the only essential.—In attempting to find out how much free moisture cropped soils should contain, it is well to bear in mind the fact that while moisture is the principal element in growing crops on arid lands it is not the only essential. Temperature, winds, sunshine, fogs, disease, and a lack of air in the soil very frequently affect crops. When, therefore, a crop is suffering an effort should be made to discover the cause and not jump to the conclusion that more water is needed.

QUANTITY TO APPLY IN ONE IRRIGATION.

What becomes of the water.—The application of 4 inches of water in depth over the surface of a field on which plants are growing fairly well is sufficient to moisten the soil to a depth of 4 feet, providing it is evenly distributed without loss. In practice a larger volume is required if it is desired to moisten the soil to this depth. This difference between theory and practice is readily explained. In irrigating in the usual way the top layer of soil receives far too much water. A part of this seeps into the second and third feet, a part passes off into the air in the form of vapor, and the balance remains in the top layer or is utilized by the plants. Now, in this process of distribution from the surface downward there is a large amount wasted. The greatest loss of water is from the surface of moist soil into the air. Thus experiments have shown that if the surface is kept moist for four days after the water is first turned on, from 1 to 2½ inches in depth over the surface will be lost by evaporation. If the soil is saturated the loss will approach the higher figures, but if the soil is only moist it will range nearer the lower figure. There is a further loss of water as it seeps downward. Some subsoils are sandy or gravelly and the water, instead of being held in the upper 4 feet, may go much deeper and soon pass beyond the deepest roots and be lost. Other fields may have a stiff clay subsoil which will not allow the water to pass through it. The effect of this is to hold the water near the surface until the greater part is evaporated. Considerable quantities of water may be allowed to run off to other fields when they are being irrigated. Hence it follows that for light irrigations, where the soil is moistened to a depth of 18 inches, from 2 to 3 inches of water over the surface would be plenty, but so great is the loss from the causes named that 4 to 6 inches are required. Similarly for heavy irrigations and for deep-rooted plants like alfalfa, 6 inches of water over the surface would convert fairly dry soil to moist soil to a depth of 4 feet, providing there was no loss, but on account of the various ways in which water may be wasted the amount required frequently exceeds 9 inches in depth over the surface.

Cultivation essential.—In localities where water is cheap and plentiful it may matter little, as regards the annual cost of the water, whether a farmer uses 6 inches at each irrigation or 12 inches. The effect of the proper use of water, however, will soon be apparent in the yield of crops and the fertility of the soil. It should be understood from the start that irrigation water can not take the place of cultivation. The labor and skill of the husbandman are needed even more in arid than in a humid climate. Repeated trials have shown that excellent crops of all kinds can be grown with a medium amount

of water, provided the soil is well cultivated and the water rightly applied.

DRAINAGE.

Experience throughout the arid region is demonstrating that the greatest danger to irrigated lands is lack of drainage. Water applied to crops raises the ground water, which brings with it the salts dissolved from the soil; capillarity brings this water to the surface, where it evaporates, leaving the salts to accumulate until all vegetation is destroyed. The only insurance against this is proper drainage. The drainage conditions are therefore equally important with the water supply and should be looked into with as much care. When there is not good natural drainage it must be supplied artificially.

While good drainage is the only guarantee against these evils anything which will check the rise of ground water or lessen evaporation will decrease the danger. The two most effective means of accomplishing these ends are economy in the use of water and thorough cultivation, and cultivation makes possible the greatest economy in the use of water. Wherever possible water should be applied in such a way that the surface soil will not be wet, and cultivation should follow as soon as possible, and be repeated often. This will check evaporation and keep the water in the soil for the use of plants, making it unnecessary to apply more so soon as it would otherwise be needed, and in this way reduce the volume which might go to damaging the land.

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